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HIGH-TEMPERATURE BAG FILTER DEVELOPMENT

Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

1961

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BAG FILTER DEVELOPMENT

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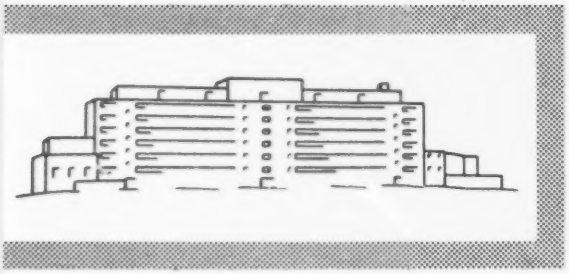

The Robert A. Taft
Sanitary Engineering Center

TECHNICAL REPORT
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U. S. DEPARTMENT OF HEALTH,
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Public Health Service

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HIGH-TEMPERATURE BAG FILTER DEVELOPMENT

Summary Report of a Study
Conducted by
Arthur D. Little, Inc.
for the
Public Health Service

April 1957 - January 1959

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Bureau of State Services
Division of Air Pollution

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HIGH-TEMPERATURE BAG FILTER DEVELOPMENT

Introduction

As part of its effort to encourage development and application of better and more economical means for cleaning high-temperature industrial effluent gases (in the range of 600-1000°F), the U. S. Public Health Service sponsored a program of work at the laboratories of Arthur D. Little, Inc. This effort was a study of high-temperature filter fabrics and methods of improving them. Work was begun in April, 1957, and concluded in January, 1959. This paper is a summary report on results that were obtained.

Outline of the Problem

In the past several decades, significant achievements have been made in air pollution control. Developments and improvements in mechanical, electrostatic, scrubber, and filter-type equipment have contributed greatly in reducing the amount of dust, smoke, and other matter discharged into the atmosphere.

Much of this progress has applied, however, to those situations where temperature did not present a problem. In the case of hot effluent streams such as those from metallurgical operations, cement kilns, power boilers, and incinerators, progress has been much slower.

One of the most effective but economical devices for fine dust and fume collection is the simple baghouse with its multiple fabric tubes or bags. Although known and used for many years, the bag filter has been limited to low-temperature applications for lack of suitable temperature-resistant fabrics. Obviously, a filter fabric or fabrics capable of satisfactory performance and good service life at high temperatures would meet a very important need. The purpose of our study was to achieve such a fabric.

Technical Approach

In the first phase, the literature and industrial sources were received for information on temperature-resistant fiber materials of possible interest. As a result of this survey, the following conclusions are presented:

a. All present organic-base fibers, natural or synthetic, are unsuitable for filter bag service in the 600-1000°F range.

b. The new carbon fibers, in their present state of development, lack the necessary strength and are much too expensive.

c. Certain fine metal fibers could be of possible technical interest; however, few metal fibers are drawn fine enough and priced low enough to make them attractive.

d. As a class, only the mineral fibers offer the thermal stability, resistance to oxidation, chemical inertness, flexibility, and strength required.

e. Of the mineral fibers, only asbestos and commercial spun glass are at present economically practical.

The entire problem thus resolved itself into a single simple question: Can mineral fiber fabrics, especially those of glass and of asbestos, be improved in performance and in service life to meet the practical needs of the high-temperature (600 to 1000°F) filter baghouse? The experimental phase of the study, therefore, was confined essentially to answering this question.

Experimental Method

In product development work, it is very helpful to have a rapid test that can reflect or represent the service function the product is to fulfill. It is of further help when such a guide test can be carried out in miniature so that testing time and cost of sample preparation are reduced correspondingly. Designing such a test requires a fundamental understanding of the property to be studied.

Two properties had to be considered. A baghouse filter must be capable of arresting particulate matter from the air or gas

stream with good efficiency. In addition, the bag material must be able to withstand a periodic cleaning cycle for release of filter cake that builds up on the inside surface. It is assumed, of course, that the bag material itself is stable in the service environment.

The question of filter efficiency was disposed of at once. In a typical bag filter the arrested particulate matter forms its own filter bed. The fabric initially can be a very poor filter; but, as a layer of filter cake builds up, bag efficiency improves enormously. Gas flow resistance increases also, so the cake must be dropped at some point determined by economic and practical considerations. The bag never returns to the completely clean condition, but retains a "priming" charge of particles so that collection efficiency remains high once established.

It is evident from this brief discussion and experience has shown that only limited control of bag filtration performance can be exercised through selection of fiber, finishes, and fabric design. Because of this and the fact that efficiency of baghouse performance, even in the temperature range of interest, has not been a critical part of the problem, no laboratory work was done on this property. Nevertheless, performance is further mentioned later in this report.

Service life of bag filters at high temperatures has been and remains a very serious problem. There was a need, therefore, to devise an accelerated test indicative of service life in a fabric so that an experimental program could be properly guided.

When a fabric of any kind deteriorates in service, a number of factors contribute. Chemical changes in the fiber substance may alter and weaken it; individual filaments may become overstressed and rupture; and finally, (ignoring external wear effects) as the fabric is flexed and worked, particularly under stress, there is abrasion as one filament moves against its neighbor, causing mutual damage and eventual failure.

In mineral fiber fabrics, there is usually good chemical stability under most circumstances. Good fabric design and careful use of the fabric will help to avoid undue fiber rupture and the resulting mechanical failure. The mineral fibers have notoriously poor abrasion resistance, however Fiberglas may be considered the typical example. Here, indeed, success of the entire industry is dependent upon the effectiveness with which each filament of product is protected from external damage. As fine as each filament may be, it is still a tiny rod of hard

glass which can contact its neighbor only at a point bearing. Even very small external pressures will result in enormous load concentrations at these contact points. Added to this is the strong tendency of glass surfaces to seize or weld upon contact. Once the surface is scratched, nicked, or otherwise marred, the fiber is easily broken. It is for this reason that a glass fiber fabric, if made perfectly clean by any means, can be readily pulverized between the fingers.

At normal temperatures, the practicability of plied and woven glass fiber structures is made possible only by use of ingenious finishing agents that protect the filament surfaces against such interfiber damage. Most of these finishes are organic and so are limited in temperature stability to something under 450°F. In addition, fine filaments present a very large surface area, so that oxidation or other chemical reaction between finish and exposure atmosphere is greatly facilitated. This presents an added problem for any libricant at high temperatures.

One important measure of resistance to wear in service is the ability of a mineral fiber fabric to withstand flexing--especially under severe conditions. Accordingly, a flexing device was built for testing various finishes and treatments that would improve service life in bag filter fabrics at high temperatures.

This test apparatus underwent some developmental changes during the fabric treatment study; for example, bearings had to be located outside the heated zone. It has been verified, however, that these minor changes did not affect the end results significantly, and therefore for this report the test apparatus was considered uniform throughout the program.

Figure 1 shows an interior view of the tester. A 0.125 inch diameter polished stainless steel rod was supported horizontally in a small transite chamber. The rod ends extended through openings in the chamber walls and rested in ball-bearing assemblies. Thus, the rod was free to rotate easily, even when the chamber interior was heated to 1000°F. The figure shows how the fabric specimen to be tested (1-3/4" wide x 6" long) was hung over the rod with a clamp fastened at each end of the specimen. One clamp was attached to an actuating arm that moved the fabric to and fro over the rotating rod or mandrel. The clamp on the down-hanging end of the fabric was attached to a tension wire and 3-pound weight. The fabric specimen was always cut with the long dimension in the warp direction.

A thermocouple junction, located close to the flexing fabric, indicated temperature in the chamber. Hinging the front panel

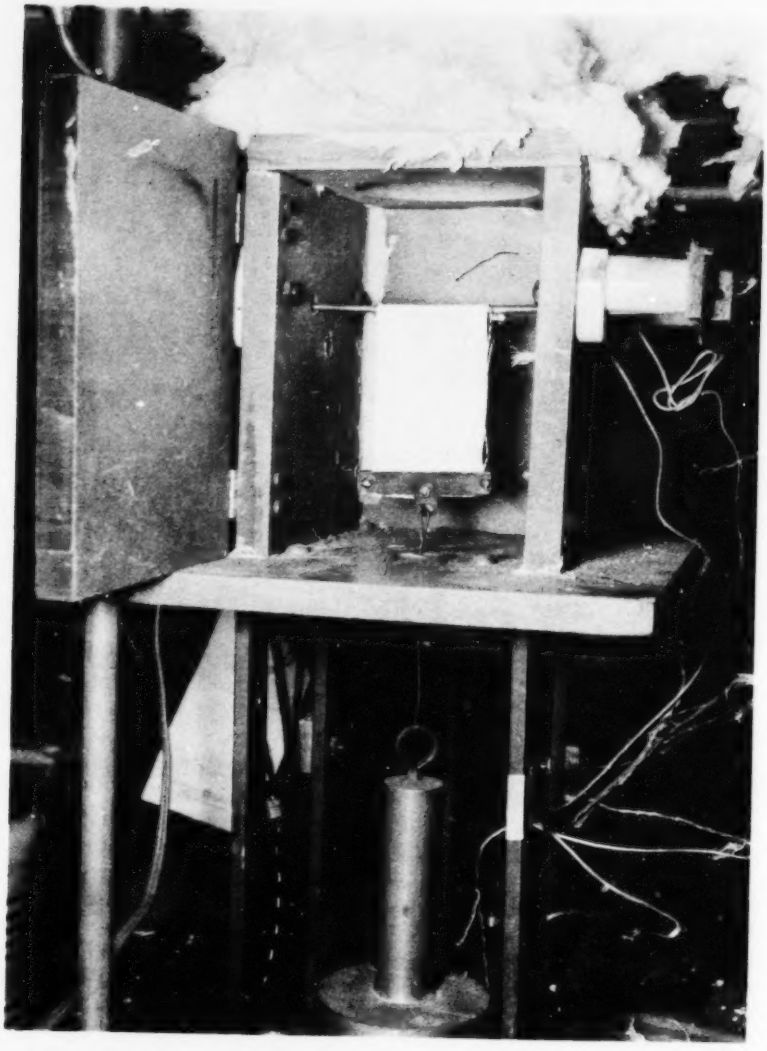

Figure 1. INTERIOR VIEW OF HIGH-TEMPERATURE FABRIC FLEX TESTER

of the chamber to swing outward allowed easy access and inspection of the sample.

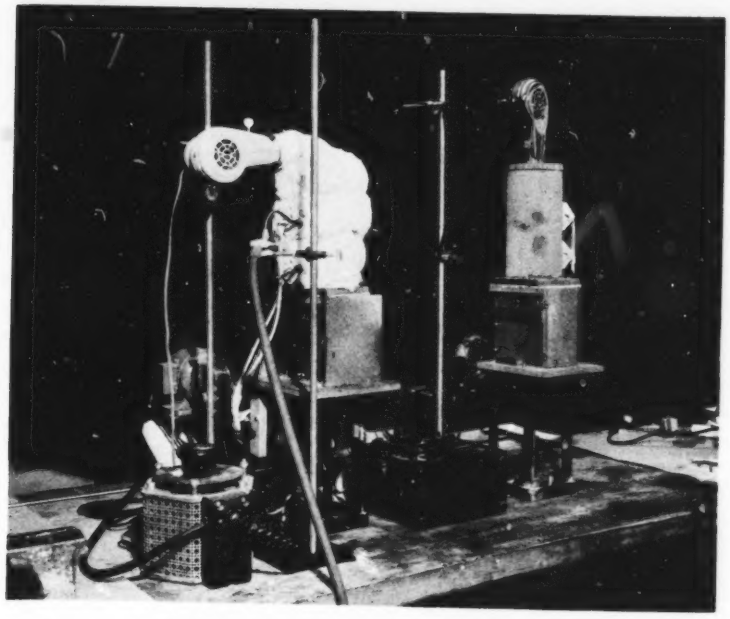

Figure 2. GENERAL VIEW OF TWO HIGH-TEMPERATURE FABRIC FLEX TESTERS

Figure 2 shows a complete arrangement for two test units. Hot air was forced into the chambers from above by ordinary hair dryers. These alone did not attain the required temperatures and therefore the air was passed through secondary heaters controlled with variable transformers. Shown also in Figure 2 are motors used to drive the crank mechanisms to actuate fabric travel. A revolution counter and an electric clock were attached to each drive. At the start of a test run, the fabric sample was mounted carefully so that it was held in tension uniformly across its width. The chamber interior was then brought to the required temperature and oscillating travel of the flexing fabric over the rotating mandrel started. Flexing rate was 41 cycles per minute, and the travel stroke 1.6 inches. Once started, the machine was allowed to run until the specimen failed; the tension weight then dropped to a control switch, shutting off all power to that test unit. In this way the length of run was indicated automatically by clock and counter.

Experimental Results

Table 1 compares the flex life of various cotton, asbestos, and glass fiber filter fabrics and shows the effect of temperature on flex life in each case. Cotton has good resistance at low temperature, but is severely limited if the temperature exceeds 300°F and fails quickly above 400°F.

Asbestos fabrics show poorer flex resistance than cotton when both are tested at low temperatures. Asbestos also loses flex resistance when run hot but retains some utility even at temperatures exceeding 700°F. Similarly, glass fiber fabrics lose flex life as the temperature is increased, but retain a large fraction of low-temperature life when run hot if the fiber surface is protected with a lubricant that is stable at the temperature of operation. Silicone treatments, for example, can provide good flex resistance to temperatures of 600°F or even somewhat higher.

Table 2 shows the wide variability of flex life values at 600°F for glass fabrics of various styles and finishes as compared to asbestos and aluminum silicate. Such data suggest that glass fiber filter bag life can be controlled to an important degree by fabric design and by selection of finish.

One of the most surprising findings was the very high flex life of a glass fiber fabric described as grey goods. Although stated to have no special treatment, this particular sample of fabric showed remarkably high resistance to breakdown (Table 2). We can attribute this only to an original finish given to the fiber or yarn before the fabric was woven.

Of the various high-temperature lubricants tested, colloidal graphite gave the best indication that improved flex wear resistance might be imparted to a glass fabric by external treatment. This is shown in Table 3. Not all graphite dispersions were effective, however, as evidenced by the last item in Table 3 (colloidal graphite dispersion A), which shows no improvement. Most of the experimental work on graphitizing was done with Dispersion B, which consistently improved flex life in all applications.

The most encouraging experiment of all was that in which Graphite Dispersion was applied to the grey goods previously mentioned. The flex-wear life at 600°F was more than doubled, giving an average flex-wear life of 55 hours--higher than that

Table 1. EFFECT OF TEMPERATURE ON FLEX RESISTANCE OF VARIOUS FILTER BAG FABRICS

Description of fabric	Fabric treatment or distinguishing feature	Temperature of test, °F	Time to failure, hr.	Remarks
Light Cotton Duck	No treatment	80	Over 20.9	All these cotton duck samples from same manufacturer (A).
Light Cotton Duck	No treatment	300	Over 10.0	
Light Cotton Duck	No treatment	400	0.77	
Heavy Cotton Duck	No treatment	300	6.8	
Heavy Cotton Duck	No treatment	400	0.78	
Asbestos Grade AA	Contains 10% cotton	80	Over 9.0	Sample not worn.
Asbestos Grade AA	Contains 10% cotton	600	1.3	All these asbestos fabrics from same manufacturer (B).
Asbestos Grade AA	Contains 10% cotton	700	0.85	
Asbestos Grade AAA	Contains 5% cotton	80	4.9	
Asbestos Grade AAA	Contains 5% cotton	600	2.5	
Asbestos Grade AAA	Contains 5% cotton	700	1.6	
Asbestos Grade AAA	Contains 5% cotton	775	1.5	
Glass Fabric 6.5 oz/yd^2	Silicone finish	80	3.1 ← 2 Tests	All these glass fiber fabrics from same manufacturer (C)
Glass Fabric 6.5 oz/yd^2	Silicone finish	600	0.2	
Glass Fabric 16 oz/yd^2	Silicone finish	80	1.4	
Glass Fabric 16 oz/yd^2	Silicone finish	600	.4 ← 3 Tests	
Glass Fabric 16 oz/yd^2	Silicone finish	1000	.8	
Glass Fabric 17 oz/yd^2	Silicone finish	80	3.8	
Glass Fabric 17 oz/yd^2	Silicone finish	600	2.0 ← 4 Tests	
Glass Fabric 17 oz/yd^2	Silicone finish	775	2.1	

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Table 2. FLEX RESISTANCE OF VARIOUS AVAILABLE MINERAL FIBER FABRICS AT 600°F

Description of Fabric	Treatment or distinguishing feature	Time to failure, hr	Remarks
Glass Fabric Style 1 Manufacturer C	Grey goods	23.2 23.0	No added treatment by manufacturer
Glass Fabric Style 2 Manufacturer C 16 oz/yd	Silicone finish	0.4	Finish applied by manufacturer
Glass Fabric Style 3 Manufacturer C 17 oz/yd	Silicone finish	2.5 2.2	Finish applied by manufacturer
Glass Fabric Style 4 Manufacturer D	Silicone finish	4.5 5.7 6.1 5.6	Finish intended to provide long life
Glass Fabric Style 5	Silicone finish	10.3 16.3	Finish intended to provide long life
Asbestos Grade AAA Manufacturer F	No finish indicated	3.6	Among the best of asbestos fabrics
Aluminum Silicate Style 6 Manufacturer E	No finish indicated	0.2	Described as high-temperature fabric
Aluminum Silicate Style 7 Manufacturer E	Contains reinforcing wire cores	1.5	

Table 3. EFFECT OF GRAPHITE TREATMENT ON FLEX RESISTANCE OF GLASS FIBER FILTER FABRICS

Description of fabric	Fabric treatment	Temperature of test, °F	Time of failure, hr	Remarks
Glass Fabric - Style 1 Grey Goods - Manufacturer C	No added treatment Tested as received	600°F	23.2 23.0	
Glass Fabric - Style 1 Grey Goods - Manufacturer C	Colloidal graphite Dispersion B applied from naphtha vehicle	600°F 600°F	41.7 61.2 53.2	Approximately 5% graphite pick-up
Glass Fabric - Style 2 16 oz/yd - Manufacturer C	No added treatment - silicone finished as received	600°F	0.4	
Glass Fabric - Style 2 16 oz/yd - Manufacturer C	Colloidal graphite Dispersion B	600°F	14.8	5% graphite
Glass Fabric - Style 3 17 oz/yd - Manufacturer C	No added treatment	600°F 600°F	2.5 2.2	
Glass Fabric - Style 3 17 oz/yd - Manufacturer C	Colloidal graphite Dispersion B Heated 440°F 1 hour	600°F	9.5 8.7	5% graphite
Glass Fabric - Style 3 17 oz/yd - Manufacturer C	Colloidal graphite Dispersion A Heated 440°F 2 hours	600°F	2.6	5% graphite

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of any other fabric tested at any temperature. This is shown in the first two items of Table 3.

It is very important in graphitizing to cover each filament in a fabric yarn with graphite particles so that these particles will remain firmly in place or at least be replaced by other particles if they are disturbed as the fabric is flexed. It is necessary, therefore, to use a well-dispersed graphite and to work this dispersion into the fabric thoroughly. In general, the amount of graphite required is in the range of 5-8 percent solids. The original 10 percent dispersion must be thinned with naphtha to get adequate penetration. Tables 1, 2, and 3 show typical experimental results of this study.

Discussion

Several important conclusions have been drawn from this study:

1. Glass fiber fabrics appear at present to be the most practicable for high temperature (600°F and possibly higher) baghouse filter units under chemical conditions that do not preclude the use of glass fibers.

2. Based on the known baghouse performance for many of the various fabrics and the known practical results of certain glass fiber finishes (silicone types, particularly) in extending glass bag performance, the laboratory techniques used are believed to provide at least an approximate indication of relative service life to be expected in practice.

3. A very great degree of control can be exercised over flex life (and presumably over practical service life) at 600°F by selection of the type of surface finish on the fibers of a glass fabric bag.

4. Colloidal graphite, carefully selected and applied, can greatly improve flex life of glass fiber fabrics at 600°F. By inference, this treatment should extend the high-temperature service life of glass fabric baghouse filter units.

5. Under practical service conditions, abrasive matter, corrosive gases, mechanical damage, and other deteriorating influences will adversely affect the service life of glass fabric bags and thereby reduce the benefits mentioned above.

Growing use of glass fabric bags in high-temperature industrial baghouse installations is providing more and more opportunity to evaluate fabric performance in service. The need for minimum movement in the fabric is recognized, and the practice of gentle cake release by periodic bag collapse and/or by sonic vibration has been established.

Certain incidental benefits provided by a glass fabric finish should not be overlooked. The silicones, for example, provide a moisture repellant film that could be important under some conditions. This same slick film promotes a clean break-away of filter cake on the release cycle, and this assures a low average flow resistance in the unit. For this same reason, the fabric structure inself can remain remarkably clean throughout, even after a long period of use.

Whether or not long exposure to a high temperature will slowly oxidize the graphite coating is not known. Periodic retreatment may be required in a practical installation. Furthermore, it is not known whether or not the graphite coating will impair filtering efficiency to any serious degree or interfere with cake release. The Taft Sanitary Engineering Center at Cincinnati, Ohio is undertaking pilot-scale tests on graphitized glass fabrics for the purpose of evaluating them more fully under conditions more closely related to those in practice. This work is now in progress.

Although the temperature range of interest in this study was 600 to 1000°F, most of the work was confined necessarily to the 600°F level because of practical temperature limitations of available finishes. Fortunately, many industrial applications are at temperatures near 600°F and it is at these temperatures that use of treated glass fabric bags is expanding at present. Needless to say, a real breakthrough in lubrication of mineral or ceramic fibers that would permit operation at higher temperatures would have a tremendous impact both on air pollution control and on suppliers of pollution control equipment.

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